Molecular Motors and Microtubules: Patterns and Self-Assembly

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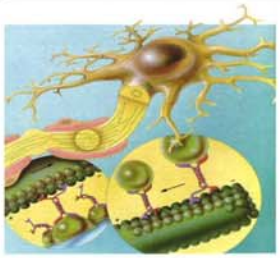
The most important function of molecular motors is to organize a network of microtubules to form cytosceletons of dividing cells. Employing the analogy between colliding grains and microtubules interacting with motors, we describe the spatio-temporal organization and the self-assembly behavior in this system. Starting from a stochastic model, we obtain a set of equations to describe the local concentration and orientation of rods. At large enough concentration of motors, the model describes the orientation instability leading to the formation of vortices and asters as seen in recent experiments.



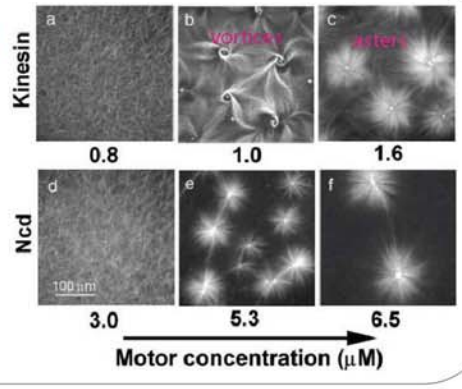
Graphics: microtubules and molecular motors functioning inside a neural filament

In-vitro experiments with microtubules and motors

(group of Prof. Stanislas Leibler, Princeton University)

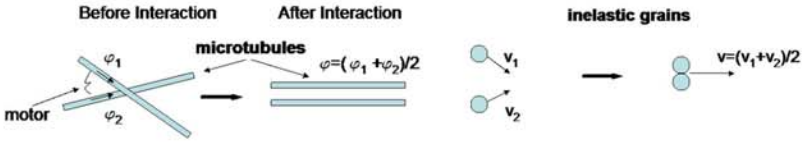
Observed:

- Spontaneous assembly of asters and vortices
- Asters are formed at large concentration of motors
- Rotating vortices are formed at lower concentration of motors



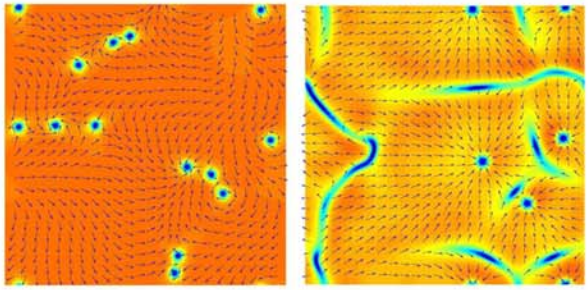
Multiscale Approach to Self-Organization of Molecular Motors and Microtubules

Main idea: mapping of interaction between microtubules and motors to inelastic interaction of polar rods (grains)



Approach:

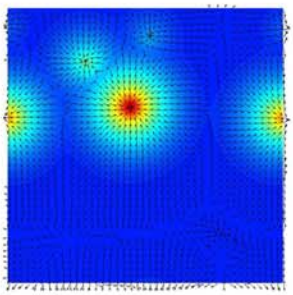
- Mesoscopic stochastic master equation for tubules orientation derived from microscopic interaction rules
- Macroscopic coarse-grained equations derived from mesoscopic stochastic master equation
- Solutions to macroscopic equations exhibit in agreement with experiment aster for high motor concentration and vortices for low concentration



Graphics: vortices (left) and asters (right) obtained by computer modeling of mathematical model

Future Plans:

- Derivation of full three-dimensional stochastic model from first-principle microscopic rules
- Specification and validation of the interaction kernel by molecular dynamics simulations and in-vitro experiments
- Extension of the multiscale approach to new types of biological and biomolecular systems



Asters in the model where the concentration of motors depends on the density of microtubules. Colors show density of motors. Red color corresponds to high concentration.

I.S. Aranson and I.S. Tsimring, *Pattern Formation of Microtubules and Molecular Motors*, Phys Rev E, v 71, 050901 (2005)

Multiscale Approach to Self-Assembly of Molecular Motors and Microtubules, Proposal funded by MICS DOS in 2006.

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This work was supported by the U.S. Department of Energy, Basic Energy Sciences, under contract W-31-109-ENG-38.

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